



PERFORMANCE EVALUATION OF NOVEL STEPPED DC LINK QUASI Z SOURCE INVERTER WITH DIFFERENT MODULATION TECHNIQUES

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ABSTRACT

This paper presents the performance evaluation of Stepped DC link Quasi Z source inverter with different modulation techniques. The proposed stepped DC link quasi Z source inverter integrates the stepped DC link circuit with the Z source inverter to yield multilevel AC voltage. This improves the quality of the output voltage and stepped DC input reduces the inrush current and minimizes the losses. The performance of the inverter varies for different modulation strategy. Hence the performance of the proposed inverter is evaluated with different modulation techniques to identify the effective modulation strategy. The circuit is simulated in MATLAB/Simulink to make a detailed study on the effect of control technique and the results are

KEYWORDS: Z source inverter, multilevel, control technique, voltage stress, voltage gain, modulation index.

I INTRODUCTION

Z source inverter has gained importance in the recent years due to its significant advantages over the conventional voltage source inverters and to name a few aresingle stage buck/boost operation, effective utilization of shoot through states and higher efficiency [1]. But it suffers from the drawback of high stress on the impedance components and the switching devices that demands high value of the network parameters. To address the drawback renovations were formulated in the topology and many new types of Z source inverters were framed in literature. The first in the class was Quasi Z source inverters that rearranged the impedance network and reduced the stress on the devices [2]. Moreover the voltage gain was improved with this topology. The extended Z source inverters were devised to improve the voltage gain obtained from the circuit [3-4]. The improved Z source inverters moved the impedance network to the backend of the inverter to obtain continuous conduction and to minimize the stress [5]. All the above configurations yield two level output voltage rich in harmonics. To minimize the harmonic content, multilevel neutral point clamped Z source inverters and quasi Z source cascaded multilevel inverters were devised that yielded buck/boosted multilevel AC voltage but utilized more number of switching devices, clamping diodes and complex switching technique [6-7]. To overcome this drawback Stepped DC link quasi Z source inverter was formulated. This integrates the stepped DC link circuit with the Quasi Z source inverter and produces multilevel AC voltage. Different topologies of stepped DC link circuit are available in literature [8] and a new topology with minimum number of switches is integrated with the Quasi Z source inverter in the proposed circuit.

The stepped DC link circuit is operated at fundamental frequency with multicarrier modulation strategy and the Quasi Z source inverter is operated at high switching frequency. The control techniques introduces the shoot through states to enable the boost function and energy storage in the impedance parameters. Many control techniques like simple boost control, maximum boost control, maximum constant boost control, maximum constant boost control with third harmonic injection, space vector modulation were framed for Z source inverters and the proposed inverter also operates with the same modulation strategy [9-11]. The performance of the proposed inverter is studied for different modulation techniques to evaluate the impact of the modulation index on the output voltage and the results are presented.

II. PROPOSED STEPPED DC LINK QUASI Z SOURCE INVERTER

The proposed stepped DC link quasi Z source inverter is a hybrid structure that uses the stepped DC link circuit with the Quasi Z source inverter to produce multilevel AC voltage [12]. The general configuration of the proposed inverter is given in Fig. 2.1

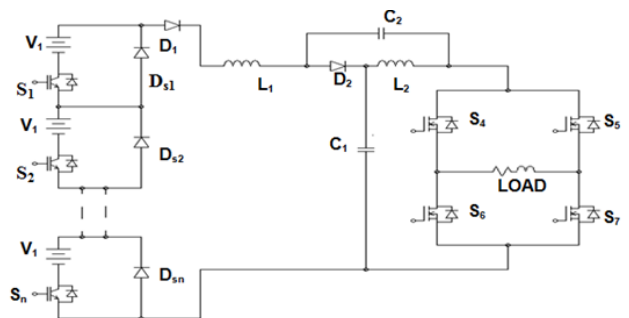


Fig. 2.1 Structure of proposed Stepped DC link Quasi Z source inverter

The inverter works under two modes, shoot through mode and the active mode. In the shoot through mode, the inverter switches are shorted and energy storage operation happens in the impedance network. During the active mode, the power flows to the load and boosted voltage appears across the load. The amount of boost depends on the modulation technique used for the inverter. The number of levels depends on the number of sources.

III. MODULATION TECHNIQUE

A. Multicarrier Modulation

The stepped DC link circuit is modulated at fundamental frequency with multicarrier modulation. Out of the various control schemes of Z source inverter, the two control schemes taken under study are simple boost control (SBC) and maximum constant boost control with third harmonic injection (MCBTHI).

B. Control Techniques of Z source inverter

The schematic of simple boost control and the maximum constant boost control with third harmonic injection is given in Fig.3.1. The

shoot through pulses is generated with the inclusion of lower and upper constant DC lines with a constant shoot through period are constant in both the cases.

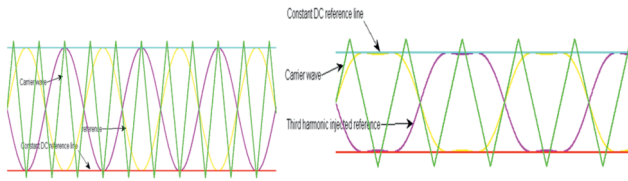


Fig.3.1 Modulation technique used for Quasi Z source inverter (a) SBC, (b) MCBTHI

The mathematical equations governing the proposed inverter are given through (1)-(4). The expression for stepped DC link voltage appearing in the circuit is given by (1)

$$V_{sdc} = V_1 + V_2 + V_3 + \dots + V_n \quad (1)$$

The generalised expression for boosted DC link voltage V_b is given by (2),

$$V_b = V_{sdc} (=nV_{in}) + \text{voltage in impedance network} \quad (2)$$

The voltage in the capacitor depends on the shoot through time period that is expressed as (3)

$$V_{c1} = \frac{T_{ns}}{T_{ns} - T_s} V_{sdc} \quad \text{and} \quad V_{c2} = \frac{T_s}{T_{ns} - T_s} V_{sdc} \quad (3)$$

The expression for boosted DC link voltage in terms of shoot through period is given as (4)

$$V_b = \frac{T_{tot}}{T_{ns} - T_s} V_{sdc} \quad (4)$$

The change in modulation index determines the voltage gain. Lower the modulation index, higher is the voltage gain. The voltage gain obtained by simple boost control technique is given by (5)

$$V_{gain} = \frac{Ma}{2Ma - 1} \quad (5)$$

The maximum constant boost control with third harmonic injection can perform over modulation and can have a higher voltage gain compared to simple boost control. The voltage gain obtained by this method is given by (6)

$$V_{gain} = \frac{3.14 * Ma}{3\sqrt{3}Ma - 3.14} \quad (6)$$

The relation between the modulation index and the voltage gain is graphically represented in the following graph shown in Fig.3.2.

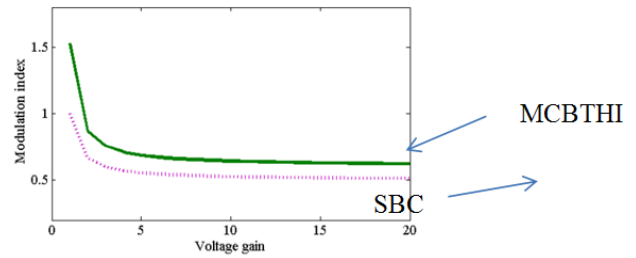


Fig. 3.2 Effect of modulation index on Voltage gain

IV. RESULTS AND DISCUSSION

The circuit shown in Fig. 2.1 was built in MATLAB / Simulink with 5 sources of 20V each. The stepped DC link voltage was modulated at fundamental frequency and the quasi Z source inverter was modulated at 10kHz. The impedance network was taken with symmetrical values of inductance and capacitance as 700mH and 0.6μF. The circuit was operated at a Ma of 0.78 and designed to produce a rated voltage of 230V(rms). The output obtained at various stages of the inverter simulated with MCBTHI is given through Fig. 4.1 to Fig. 4.3. Table I shows the switching of the various switches of the inverter. It is found that constant shoot through period is produced by the switching scheme. The constant shoot through period is 0.001 sec and the readings were tabulated for a switching frequency of 0.1kHz.

Table 1 Switching signals for the proposed inverter with constant shoot through states, $f_c = 0.1\text{kHz}$

Time period(s)	Stepped DC link switches					Inverter switches			
	S1	S2	S3	S4	S5	Sinv 1	Sinv 2	Sinv3	Sinv4
0-0.002	ON	OFF	OFF	OFF	OFF	ON	ON	ON	OFF
0.002-0.003	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON
0.003-0.007	ON	ON	OFF	OFF	OFF	OFF	ON	ON	OFF
0.007-0.008	ON	ON	ON	OFF	OFF	ON	ON	ON	ON
0.008-0.01	ON	ON	ON	ON	OFF	ON	OFF	ON	OFF
0.01-0.012	ON	ON	ON	ON	OFF	ON	OFF	OFF	ON
0.012-0.013	ON	ON	ON	ON	ON	ON	ON	ON	ON
0.013-0.017	ON	ON	ON	ON	ON	ON	OFF	OFF	ON

Fig. 4.1 gives the stepped DC link voltage obtained across the DC link circuit. The number of levels depends on the number of sources used.

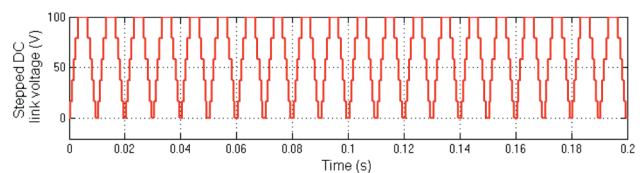


Fig. 4.1 Simulated output voltage of stepped DC link circuit

The waveform of the input current obtained is shown in Fig.4.2. It is seen that no inrush current is present, this is due to the low voltage appearing across the circuit during the initial condition. The boosted stepped DC link voltage takes the shape of stepped wave and boosted to 582V.

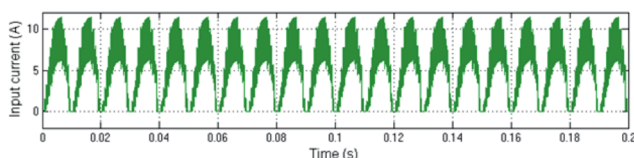


Fig. 4.2 Simulated input current of proposed inverter

The output voltage appearing across the inverter is shown in Fig. 4.3. It takes the shape of a stepped sinusoid compared to square wave of conventional QZSI. The harmonics are reduced and yields a better output in the proposed inverter.

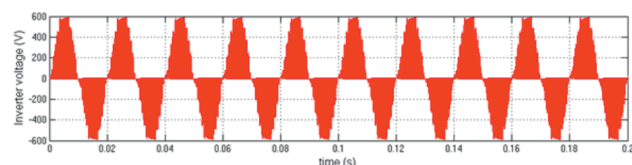


Fig. 6. Simulated boosted DC link voltage of proposed inverter

The simulations were repeated with SBC and the comparative results are tabulated in Table II. It is found that MCBTHI produces less voltage stress and inductor current ripple compared to SBC and has got a higher boost value. Hence a higher modulation index can be used to obtain the desired voltage compared to SBC. The lowering of stress minimizes the capacitor requirement and hence the cost of the system.

Table II Comparative evaluation on performance of proposed inverter for different Ma, Vin=20V per DC source

Operating Condition	Output voltage (V)peak		Inductor current ripple (A)		Capacitor voltage stress (V)	
	SBC	MCBTHI	SBC	MCBTHI	SBC	MCBTHI
M=0.7	211	264	5.6	4.3	370	320
M=0.8	152	198	4.1	3.2	294	260
M=0.9	103	132	3.5	2.4	196	184
M=1	82	98	2.8	2.1	159	138
M=1.1	73	84	2.1	1.8	130	110

From the above results it is seen that MCBTHI produces convincing results for the proposed inverter and minimizes the requirements of impedance network of the system.

V. CONCLUSION

The performance of the new stepped DC link quasi Z source inverter with two different modulation techniques was studied and the results were presented. It is found that the maximum constant boost with third harmonic injection produces a better performance in terms of voltage boost, inductor current ripple and stress. The inverter can be operated with wide range of modulation index in MCBTHI and is more suitable for the proposed stepped DC link quasi Z source inverter.

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